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(54) Magnetic linear or rotary position transducer

(57) For measuring the position of a moving body, a linear or annular measurement member (21) made of magnetic material is secured to the moving body and an E-shaped magnet (28) is positioned adjacent the measurement member. A Hall-effect IC (29) for converting variation of magnetic flux density to variation of voltage is secured to an end of the central leg portion of the magnet (28). The linear measurement member shown in Fig. 8 is an elongate bar having a series of indentations (22, 23) on each side, projections (24, 25) formed by the indentations, and a central common portion (26) having the same height as the projections (24, 25). The projections of each side are staggered relative to those on the other side. The Hall IC (29) is adjacent to the central common portion (26) and the ends poles of the magnet are adjacent the paths of travel of the projections (24, 25).

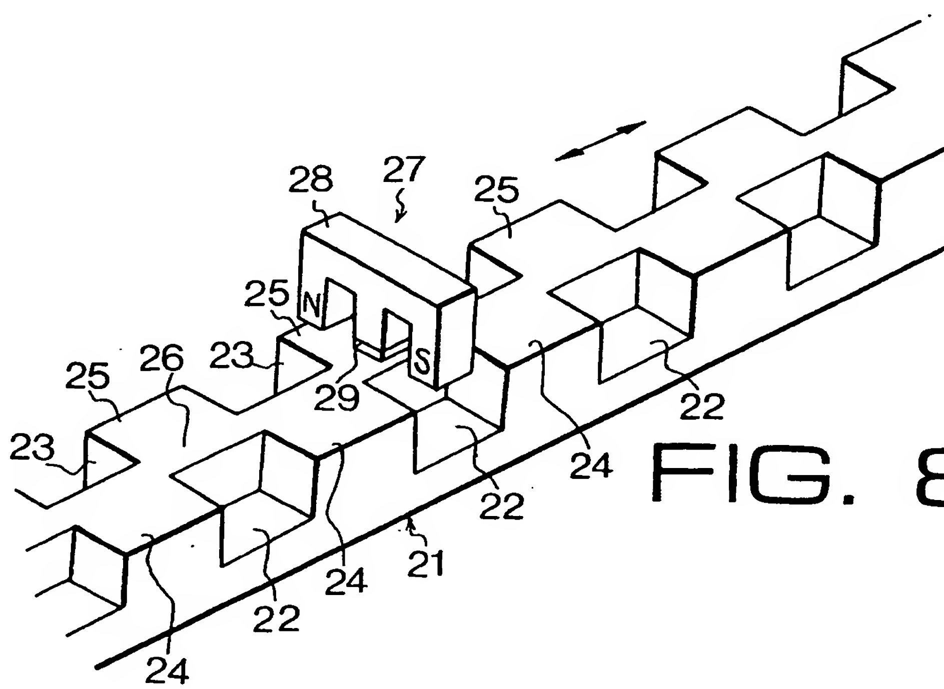

FIG. 8

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FIG. 1

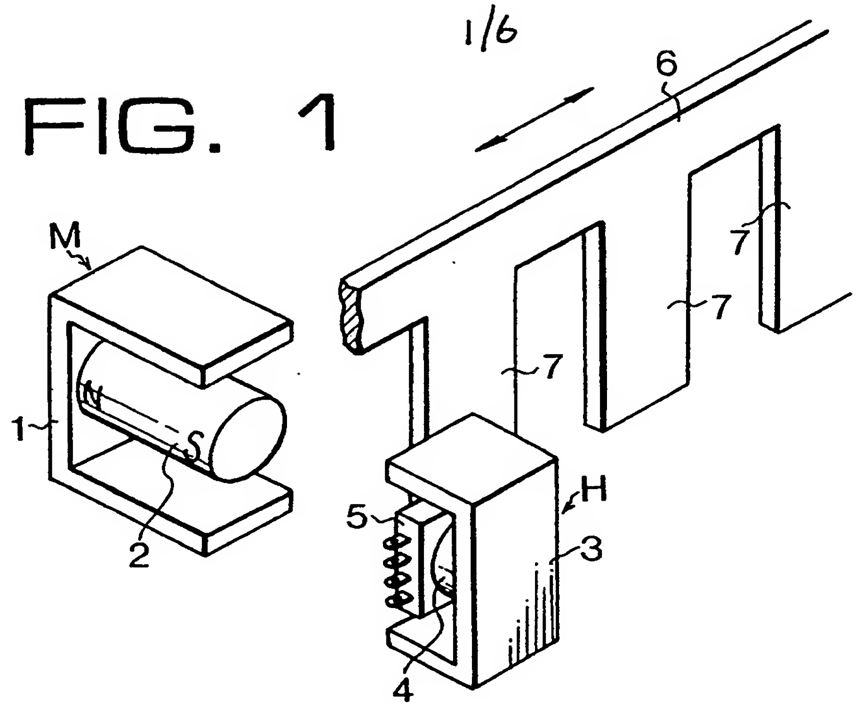


FIG. 2

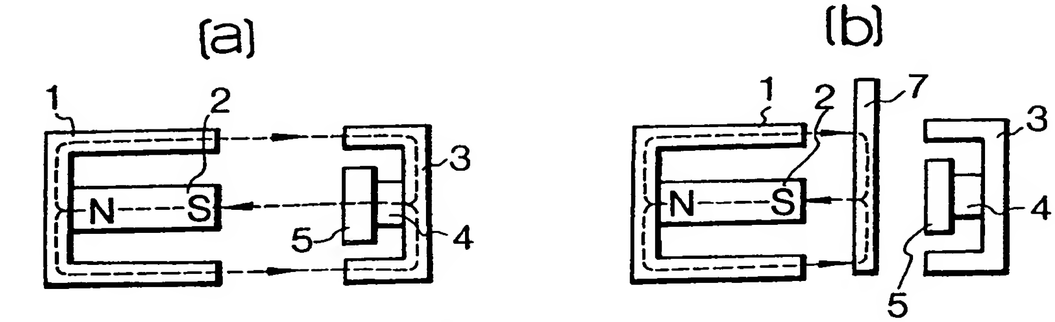


FIG. 3

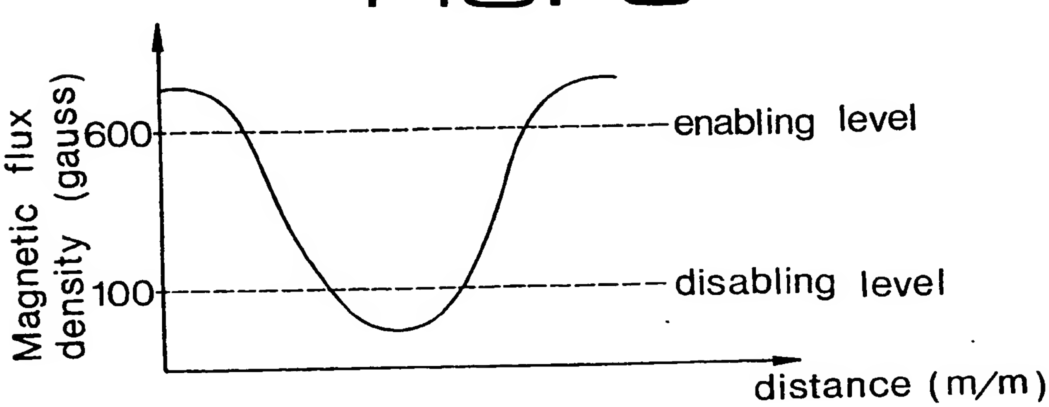
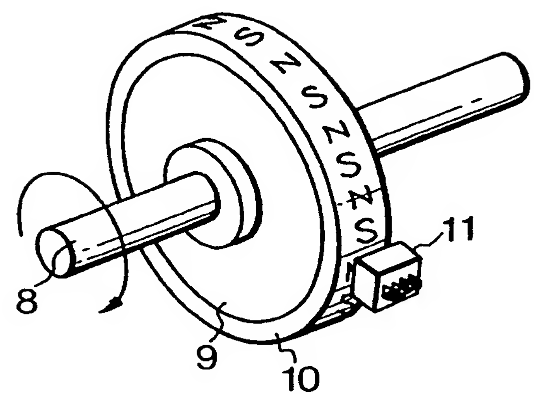


FIG. 4



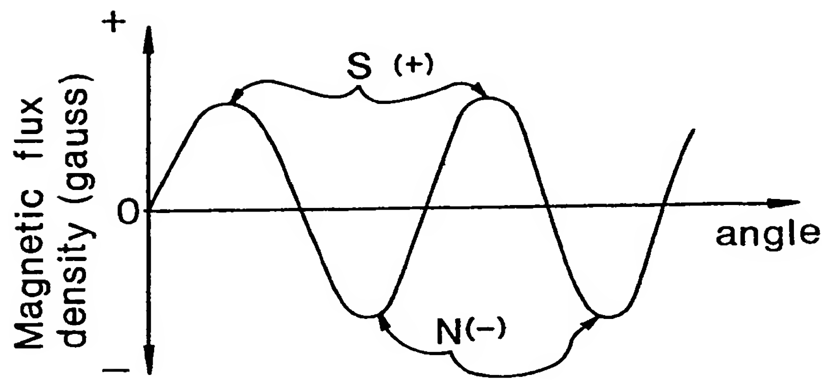


FIG. 5

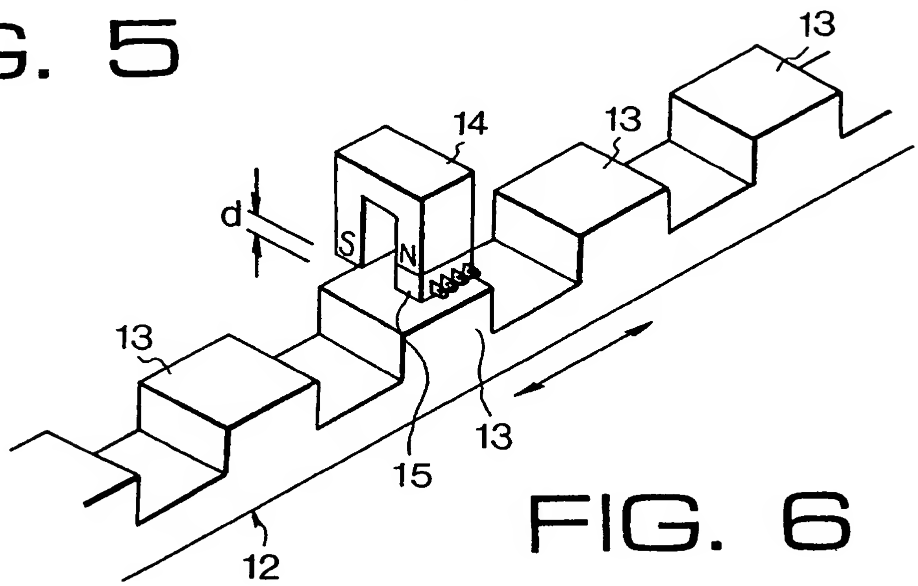
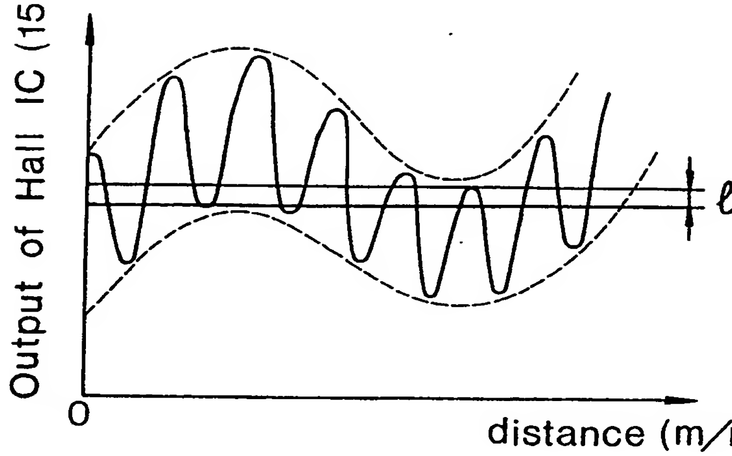


FIG. 6

FIG. 7



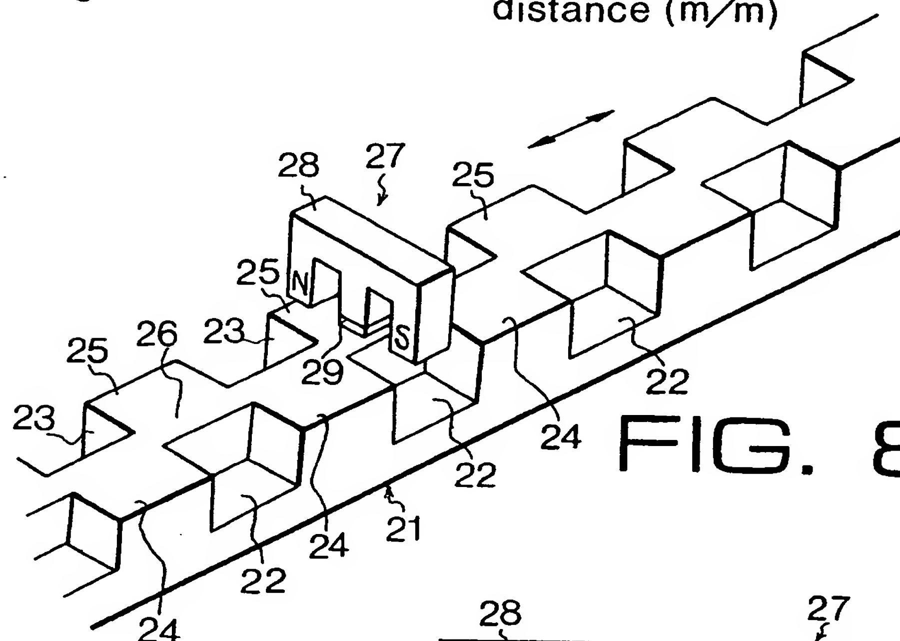


FIG. 8

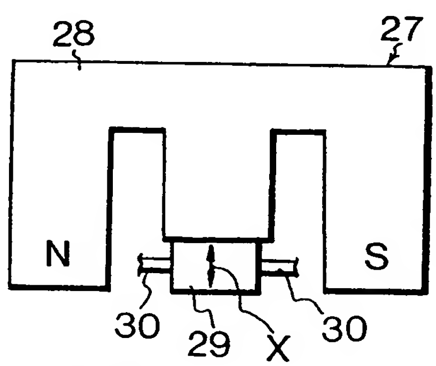
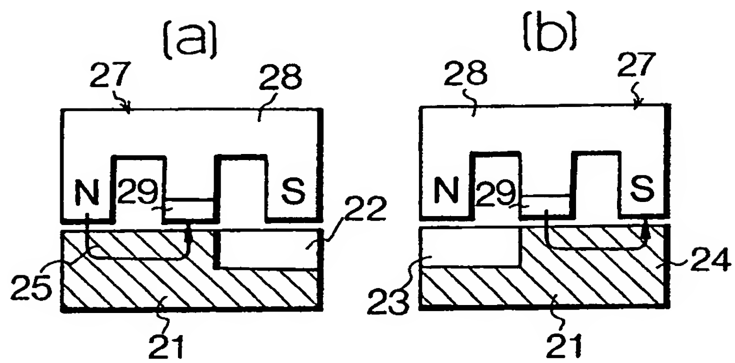


FIG. 9

FIG.10



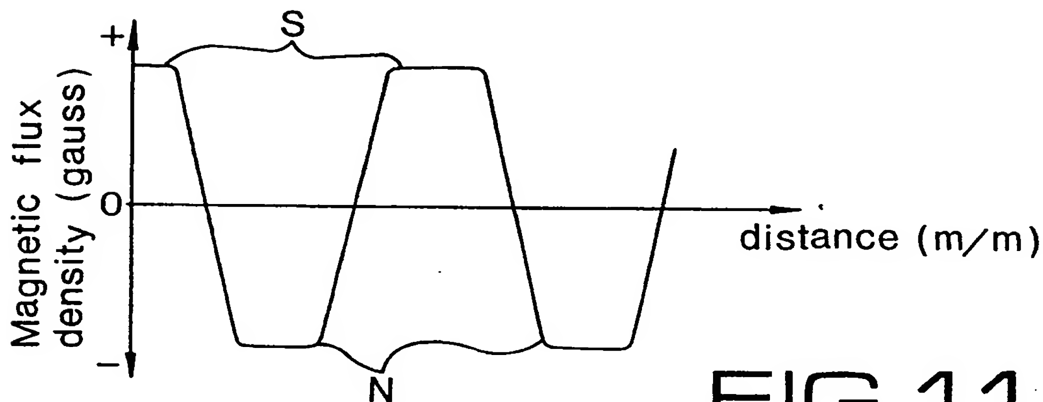


FIG.11

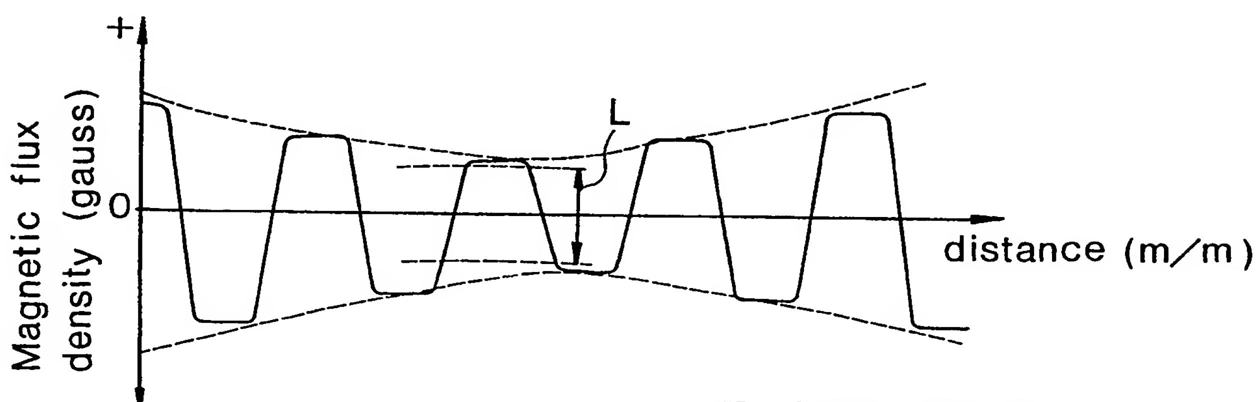


FIG.12

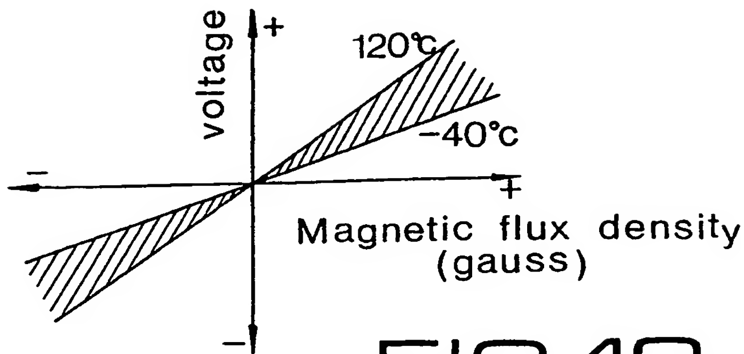


FIG.13

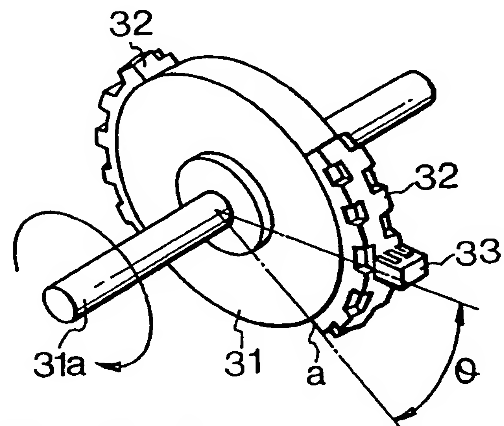


FIG.14

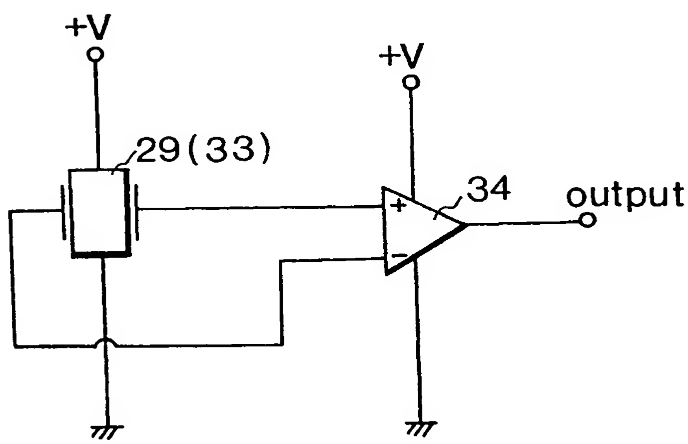


FIG.15

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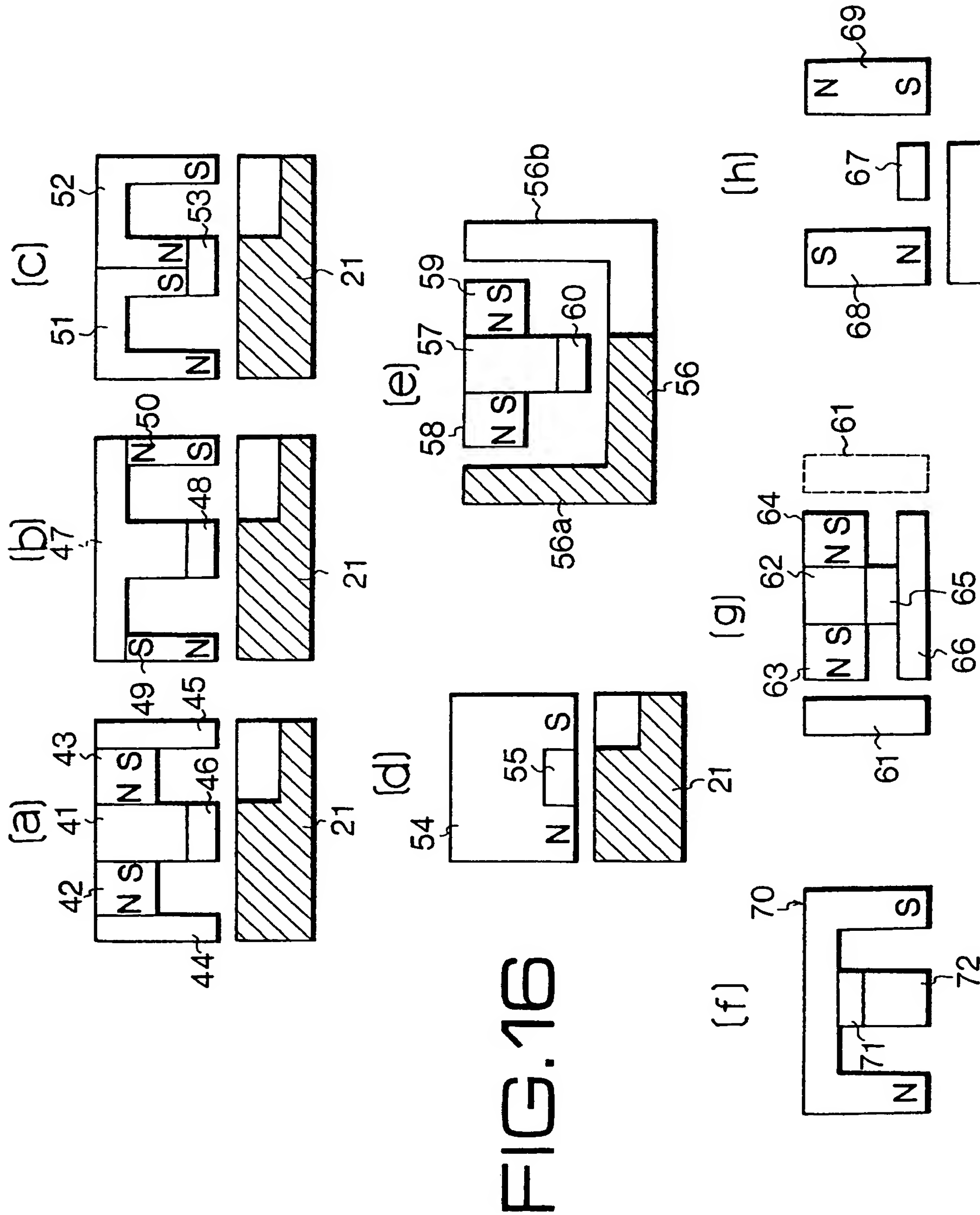

FIG.16

SPECIFICATION

Position measuring device

The present invention relates to a device for measuring a position of a travelling or rotating object and for coverting the measurement into an electrical signal.

A position sensor having a Hall element as a device sensitive to a magnetic flux has been used for detecting the position of a travelling part of a machine tool or the crankshaft of an internal combustion engine.

The previously proposed position sensor cannot accurately measure the position of a moving body as will be described hereinafter in detail.

An object of the present invention is to provide a position sensor which measures accurately a position of an object and is relatively insensitive to variations in the distance between the sensor head and the object sensed and to temperature variations.

According to the present invention, a device for measuring the position of a moving body comprising magnetic means for producing two magnetic fields; converting means for converting variation in magnetic flux density into voltage variation; and at least one measurement member which is made of magnetic material for forming magnetic circuits for the magnetic fields, which is arranged adjacent to the converting means and the magnetic means, the measurement member on the one hand and the converting means and the magnetic means on the other hand in use moving relative to one another according to movement of the moving body; the measurement member being so arranged that the polarity of the magnetic circuit for the converting means is alternately inverted on relative movement between the member and the converting means.

The invention will be more readily understood by way of example from the following description of position sensors in accordance therewith, reference being made to the accompanying drawings, in which:

Figure 1 is a perspective view showing a previously proposed position sensor;

Figures 2a and 2b explain the operation of the position sensor of Figure 1;

Figure 3 shows an output waveform of the position sensor;

Figure 4 is a perspective view showing a previously proposed angular position sensor;

Figure 5 is an output waveform of the angular position sensor;

Figure 6 is a perspective view showing another previously proposed position sensor;

Figure 7 shows an output waveform of the position sensor of Figure 6;

Figure 8 is a perspective view showing a position measuring device according to one embodiment of the present invention;

Figure 9 is a front view showing a position sensor head;

Figures 10a and 10b are illustrations for explaining the operation of the position sensing device of Figures 8 and 9;

Figure 11 shows an output waveform of the sensor;

Figure 12 shows an output waveform when the distance between a sensor head and an object varies;

Figure 13 shows the changes in output characteristic of the position sensor when temperature varies;

Figure 14 is a perspective view showing another embodiment of the present invention;

Figure 15 is an electric circuit for producing an output in the position sensor; and

Figures 16a and 16h show modifications of the position sensor.

Referring to Figure 1 shows a previously proposed position sensor for a travelling body. A U-shaped yoke 1 made of permeable material and a cylindrical permanent magnet 2 are secured to each other to form an E-shaped magnetic field producing device M. A sensor head H is positioned adjacent the magnetic field generating member. The sensor head H comprises a U-shaped yoke 3 and a core 4 secured to the yoke 3 at a centre to form an E-shaped member corresponding to the E-shaped magnetic field producing device. A Hall effect integrated circuit (IC) 5 as a magnetic flux density sensitive device is secured to the end of the core 4. A shield member 6 made of permeable material is secured to a travelling body (not shown) and adapted to pass in a straight line through a gap between the magnetic field producing device M and the sensor head H. The shield member 6 comprises a series of equally spaced teeth 7.

Describing the operation of the position sensor, Figure 2a shows the condition where a gap between the teeth 7 coincides with the sensor head H and Figure 2b shows the condition where one of the teeth 7 is positioned between the head H and the device M. In the condition of Figure 2a, a magnetic field is produced as shown by the lines of force to form a closed magnetic circuit passing through the Hall IC 5. The Hall IC 5 is then enabled. When a tooth 7 isolates the magnetic circuit as shown in Figure 2b, the Hall IC is disabled.

Figure 3 shows variation of the magnetic flux density. The magnetic flux density varies sinusoidally with the movement of the shield member 6. When the magnetic flux density exceeds the enabling level, the output of the Hall IC goes to a high level, and when the magnetic flux density decreases below the disabling level, the output of the Hall IC goes to low level. The movement of a body can thus be measured by counting the output pulses of the Hall IC.

In the position sensor of Figure 1, the shield member 6 moves between the magnetic field producing device M and the sensor head H. Accordingly, the shield member 6 must be made of thin plate. As a result, the strength of the shield member 6 is reduced, and the member 6 cannot be used for

measurement over a long distance.

Figure 4 shows a conventional angular position sensor. A circular plate 9 is fixed to a rotary shaft 8 and an annular magnetic member 10 is secured to the periphery of the circular plate 9. The magnetic member 10 is magnetized with the alternate polarity arrangement illustrated in the figure. A Hall IC 11 is positioned adjacent the magnetic member 10.

The magnetic flux density for the Hall IC 11 varies as shown in Figure 5. Since the polarity of the magnetic flux is inverted, pulses having a definite waveform can be produced by the Hall IC 11. However, it is difficult to magnetize the magnetic member 10 to an exact pattern. A position sensor to eliminate above described disadvantages is disclosed in Japanese Patent Application No. 55-137222. That position sensor, as shown in Figure 6, comprises a measurement member 12 having a series of cubic projections 13 and a permanent magnet 14 positioned adjacent the projection. A Hall IC 15 is secured to the north pole N. The south pole S and the Hall IC are positioned at a distance "d" apart from the upper surface of the projection 13. When the measured body 12 travels in the longitudinal direction, magnetic flux density for the Hall IC 15 varies in dependency on the movement of projections 13. The travelling distance can thus be measured.

However, in this position sensor, if the distance "d" fluctuates, the output of the Hall IC 15 varies, even if the magnetic flux density is constant. Accordingly, the measurement member 12 must be exactly shaped and moved to avoid variation in the distance "d". Further, the output of the Hall element varies with the variation of environmental temperature. Figure 7 shows variation of the output of the Hall element with variations of the distance "d" and temperature. Because of such a variation of the output of the Hall element, a slice level for deciding a switching level must be set within a narrow range "l". If the slice level is set at an improper level, the position of the moving body cannot be exactly measured.

Figure 8 shows a position measuring device according to one embodiment of the present invention. The device comprises a measurement member 21 secured to a moving body (not shown) and a position sensor head 27 suitably supported by means (not shown). The measurement member 21 is made of soft magnetic material such as iron or silicon steel. The measurement body is an elongate bar and has a series of indentations 22 and 23 on both sides, projections 24 and 25 formed between the indentations 22 and 23, and a common central portion 26 having the same height as the projections 24 and 25. The projections on each side are equally spaced and staggered in relation to the projections on the other side.

The position sensor head 27 comprises a magnet 28 made of hard magnetic material such as alnico or rare-earth magnet, and a Hall-effect IC 29. The magnet 28 has an E-shaped core with poles N, S at the extreme ends, and the Hall IC 29 is secured to the end of the central portion. As shown in Figure 9, the undersides of both the poles N, S and the Hall IC 29 lie in a common plane and are so arranged that the north pole N is adjacent to the projections 25 on one side of the member 21 and the south pole S is adjacent to the projections 24 on the other side, and the Hall IC 29 is adjacent to the common portion 26. The Hall IC 29 is subjected to magnetic flux in the direction of "X" and has a pair of terminal leads 30.

In operation, when the measured member 21 travels longitudinally as shown by the arrow (Figure 8), each projection 24 and 25 passes alternately through the magnetic field of the magnet 28. When the projection 25 is adjacent to the north pole N as shown in Figure 10a, the Hall IC 29 is in a magnetic field having a polarity shown by the arrow X. On the contrary, when the projection 24 is in the magnetic field, the Hall IC 29 is subjected to the magnetic field of reverse polarity.

Figure 11 shows the magnetic flux density of the magnetic field acting on the Hall IC 29. The magnetic flux density varies with a rectangular waveform and the polarity reverses with respect to the zero level.

Figure 12 shows variation of the magnetic flux density when the distance between the measured member 21 and the Hall IC 29 fluctuates. Since the magnetic flux density varies with respect to the zero level, a wide range "L" for the slice level setting can be obtained.

Figure 13 shows temperature characteristics of the Hall IC 29. The output of the Hall IC 29 varies with the variations of the environmental temperature, even if the magnetic flux density is constant. However, the output of the Hall IC becomes zero at the zero level of the magnetic flux density and varies in proportion to the magnetic flux density. Thus, in accordance with the present invention, it is possible to measure the position of a moving body with accuracy irrespective of variations in the distance between the sensor head and the measured member and in the environmental temperature.

Figure 14 shows an angular position detecting device according to the embodiment of the present invention, for example a device for measuring the angular position of the crankshaft of an internal combustion engine. A disc 31 is fixed to a rotary shaft 30. A pair of measurement members 32 each having the same projection arrangement as the device of Figure 8 are secured on the periphery of the disc 31 at suitable distances. A position sensor head 33 is provided adjacent the projections of the measurement member 32.

In the device, the angular position "θ" from an end "a" is measured by counting the output pulses of the Hall IC of the position sensor head 33. Thus, for example, the positions of top dead centre and bottom dead centre of the crankshaft and the ignition timing can be detected.

Figure 15 shows a circuit for producing output pulses with the Hall IC (or Hall element) 29. The output terminals of the Hall IC are connected to the inputs of a comparator 34. Since the output of the Hall IC is inverted at the zero level of the magnetic flux density, the output of the comparator 34 is also inverted at the zero voltage of the output of the Hall IC.

Figures 16a to 16h show various modifications. In

the device of Figure 16a, a position sensor head comprises yokes 41, 44 and 45 and two horizontal magnets 42, 43 disposed between the yokes. A Hall IC 46 is secured to the end of the central yoke 41. The magnets 42 and 43 are arranged in reverse polarity to magnetize the yokes 44 and 45 with opposite polarities.

The position sensor head of Figure 16b comprises a T-shaped yoke 47, a pair of vertical magnets 49 and 50 secured to the end portions of the yoke 47 with opposite polarity, and a Hall IC 48 secured to the end of the central leg portion of the yoke 47.

The sensor head of Figure 16c comprises a pair of U-shaped magnets 51 and 52 which are disposed with opposite polarity and are secured to each other to form an E-shaped magnet, and a Hall IC 53 secured to the central composite pole of the magnet.

In Figure 16d, the sensor head comprises a single rectangular magnet 54 having a central recess in which is embedded a Hall IC 55. The magnet is magnetized to form opposite poles at the sides as shown.

The position measuring device of Figure 16e has a measurement member 56 of U-shaped cross section, with staggered sets of projections 56a and 56b. The sensor head comprises a central yoke 57; a pair of magnets 58 and 59 on opposite sides of the yoke 57 and a Hall IC 60 secured to a lower end of the yoke. The magnets 58 and 59 are disposed with opposite polarities adjacent to projections 56a and 56b respectively.

Figure 16f shows another device in which two series of magnetic strips 61 are disposed adjacent opposite sides of a sensor head in staggered relation. The sensor head comprises a central yoke 62, a pair of magnets 63 and 64 secured to opposite sides of yoke 62, a Hall IC 65 secured to the underside of the yoke 62, and a horizontal yoke 66 secured to the Hall IC 65.

The sensor head of Figure 16g has a pair of magnets 68, 69 arranged with opposite polarities and a Hall IC 67 disposed between the magnets.

Figure 16h shows a sensor head comprising a U-shaped magnet 70, a Hall IC 71 secured centrally to the magnet, and a yoke 72 secured to the Hall IC 71.

The measuring device described are capable of measuring the position of a moving body with accuracy even if the distance between the sensor head and the moving body fluctuates and if the environmental temperature varies. Although, in above described embodiments, the Hall element or Hall IC is employed as a device for converting variations in the magnetic flux density to variations of voltage, other elements such as magnetoresistor may be employed. Further it will be understood that the sensor head may be secured to the moving body and the measurement member held stationary.

CLAIMS

1. A device for measuring the position of a moving body comprising: magnetic means for producing two magnetic fields; converting means for converting variation in magnetic flux density into voltage variation; and at least one measurement member which is made of magnetic material for forming magnetic circuits for the magnetic fields, which is arranged adjacent to the converting means and the magnetic means, the measurement member on the one hand and the converting means and the magnetic means on the other hand in use moving relative to one another according to movement of the moving body; the measurement member being so arranged that the polarity of the magnetic circuit for the converting means is alternately inverted on relative movement between the member and the converting means.

2. A position measuring device according to claim 1, wherein the magnetic means is an E-shaped magnet.

3. A position measuring device according to claim 2, wherein the converting means is mounted on an end of the central leg portion of the E-shaped magnet.

4. A position measuring device according to claim 1, further comprising a yoke for connecting the converting means and the magnetic means.

5. A position measuring device according to claim 1, further comprising a yoke secured to the converting means to be adjacent the member.

6. A position measuring device according to any one of claims 1 to 5, wherein the member comprises an elongate bar which has a series of indentations on each side spaced by projections formed by the indentations, and a common central portion having the same height as the projections, the projections on one side being staggered relative to those on the other side.

7. A position measuring device according to claim 3 and claim 6, wherein one end pole of the E-shaped magnet are adjacent the projections of one side of the member and the other end poles are adjacent the projections on the other side, and the converting means is adjacent the common central portion.

8. A position measuring device according to any one of claims 1 to 5, wherein the member has a U-shaped cross section and comprises a plurality of projections which are staggered.

9. A position measuring device according to any one of claims 1 to 5, wherein the measured member comprises a plurality of strips.

10. A position measuring device according to any one of the preceding claims, wherein the converting means is a Hall element.

11. A position measuring device according to claim 10, wherein the converting means is a Hall integrated circuit.

12. A position measuring device according to any one of claims 1 to 9, wherein the converting means is a magnetoresistor.

13. A device for measuring the position of a moving body, substantially as herein described with reference to Figures 8 to 16.

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